FACTORS AFFECTING THE QUALITY OF GRAPEFRUIT EXPORTED FROM FLORIDA

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T. T. Hatton, Jr., Currie F. Melvin, M. Bryan Sunday (deceased), and other members of the Horticultural Crops Branch, Market Quality Research Division, at Orlando, Fla., assisted in obtaining test fruit and collecting data.

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Factors Affecting the Quality of Grapefruit Exported From Florida

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SUMMARY

In tests with Marsh Seedless and Ruby Red grapefruit, a 60° F. export transit temperature was best for early-harvest fruit. Little rind breakdown and decay occurred at this temperature in either the simulated tests or shipments that were accompanied by an observer.

On more mature fruit of mid- and late-season harvest, a transit temperature of 50° F. was best. Little difference was noted in the condition of this more mature fruit after it had been stored at 50° and 60°, the simulated export temperatures. In the accompanied test shipment and a test with *Penicillium* inoculated fruit, a 50° stowage temperature minimized development of decay in grapefruit. Transit temperatures of 32° and 40° were found to be less desirable than 50° or 60° for grapefruit because of the development of excessive amounts of rind breakdown, brown staining, and decay. Early-season Marsh Seedless and Ruby Red grapefruit had a greater tendency to develop pitting than more mature fruit, whereas late-season fruit tended to be more susceptible to aging and decay than early- and mid-season fruit.

Degreening after harvest, either naturally or with ethylene, is necessary from September to about January to remove green color from the rind for consumer acceptance of grapefruit. Natural degreening of unwaxed green-colored fruit occurred during a 3-week 60° F. transit period. However, shriveling or loss of moisture was noted during the 2-week holding period. Degreening by ethylene before transit is necessary for waxed grapefruit.

Waxing reduced weight loss, improved the appearance, and reduced rind breakdown at 32° and 40° F.

A treatment with orthophenylphenol or biphenyl is essential to aid in controlling blue-green mold and stem-end decay as fruit moves through the market.

Fruit held prior to export or for any long-term storage after transit should be held at the recommended transit temperature.

Results of the accompanied export tests of Florida grapefruit substantiated the findings of the simulated export tests as to treatment and temperature. When fruit was severely bruised by rough handling and a stormy ocean transit, decay developed rapidly during the marketing period.

Rough handling, improper stacking, and improper use of dunnage caused damage to container and fruit, and resulted in excessive loss from spoilage and poor market quality of the fruit.

INTRODUCTION

Transportation of grapefruit to oversea markets presents problems similar to those encountered in refrigerated storage. The most important problem is selection of proper temperatures for the 2- to 4-week export transit period for fruit shipped at various maturities from early fall to late spring. Considerable differences in the recommended temperatures for the storage of grapefruit have been reported, including 32° F. (*4, 13, 18, 19, 20, 42*),[1] 37.5° (*37*), 45° to 50° (*2, 7, 10, 15, 16, 24, 25, 34, 41, 42*), and 55° to 60° (*3, 20, 27, 31, 32, 38, 39, 40*). These recommendations did not adequately consider the possibility that fruit of different maturities might require different temperatures. Most fruit destined for domestic storage is harvested in late spring and consequently is of advanced maturity. Of major concern to exporters has been the susceptibility of grapefruit to rind breakdown in early fall shipments and to decay in late spring shipments.

Preparation of the fruit by treatments, such as degreening and application of fungicides and wax, and handling procedures before shipment also affect the condition of the fruit on arrival in oversea markets and during the marketing period.

[1] Italic numbers in parentheses refer to Literature Cited, p. 20.

This report summarizes the results of simulated export studies conducted at the U.S. Department of Agriculture Horticultural Field Station, Orlando, Fla., and test shipments of Florida grapefruit to West Germany in 1961–62, 1962–63, and 1963–64 seasons. An observer accompanied the test shipments. The objective was to determine optimum environments for reduction of spoilage and maintenance of quality of fruit exported for the European market.

LITERATURE REVIEW

In all reports concerned with the export of citrus, one of the first recommendations is that only *top quality* fruit be selected for oversea shipment (*14, 17, 28, 41*).

Many of the pretransit treatments affect the condition of the fruit at destination. For instance, the removal of green rind color of Florida citrus fruits by ethylene early in the season (September to January) is standard practice. Degreening by this means often increases stem-end decay and under low humidity causes "gas burn." *Penicillium* decay is usually decreased by the degreening process because the fungus is weakened at temperatures above 75° F. (*8, 9, 22*).

Citrus fruits are waxed to replace the natural wax removed in washing, to reduce weight loss, and to increase consumer appeal (*26*). One of the major benefits of waxing grapefruit destined for storage and possible exposure to low relative humidities is the prevention of shrinkage due to loss of moisture (*42*). A good application of wax may reduce the weight loss by 40 to 50 percent when compared to the unwaxed fruit of the same lot (*26*). Fungicides are often incorporated in the wax.

To understand how best to control decay, one must first understand the postharvest diseases involved. Stem-end decay, which is caused by *Diplodia natalensis* or *Phomopsis citri*, occurs on fruit grown under humid conditions such as exist in Florida. These infections are often present on the fruit at harvesttime, but decay does not develop until after the fruit is removed from the tree (*33*).

Penicillium digitatum, or green mold, occurs on fruit from all citrus-growing areas in the world. The major factor required for infection by green mold is a mechanical injury to the skin of the fruit during harvesting or subsequent handling. No protection is afforded to the fruit if the skin break is caused after the initial application of a fungicide at the packinghouse. Therefore, the opportunities for infection during packing, loading, and shipment are numerous (*33*).

The best treatment available for reduction of both stem-end rot and green-mold decay is the application of sodium orthophenylphenate plus hexamine and the use of biphenyl-impregnated pads. The sodium orthophenylphenate plus hexamine inhibits the growth of decay organisms present immediately after harvest. The biphenyl volatilizes slowly and maintains an atmosphere in the container that reduces the incidence of both decays and prevents the development of the mature *Penicillium* spores during the storage and marketing period (*16, 21, 23, 35, 36, 41*).

Market disorders of grapefruit other than decay include pitting, aging, brown staining, and bruising (*30, 33*).

The 2- to 4-week export transit period can be considered as storage, and information developed in previous storage studies may be helpful in determining optimum export transit environments.

Hawkins and Magness (*19*) reported that the best storage temperatures for Florida grapefruit was 32° F. Rind breakdown or pitting of the peel developed at 40° but apparently did not develop at higher or lower temperatures. Harding et al. (*12*) concluded that grapefruit could not be held for much longer than 4 weeks at 32°. They also reported that some decay control resulted from prestorage treatments of sodium orthophenylphenate plus hexamine, but the use of these compounds did not extend the storage life of the fruit. Harding, Soule, and Sunday (*13*) reported the pattern that so often resulted when grapefruit was stored at 32°, 40°, and 50°: Grapefruit stored at 32° and 40° developed considerable decay after 5 or 7 days of the poststorage period. Fruit stored at 50° nearly always developed more decay during storage.

Brooks and McColloch (*2*) with Florida grapefruit, Ryall and Buford (*34*) with Texas grapefruit, Harvey and Rygg (*15*) with California grapefruit, and Leonard (*25*) with Trinidad grapefruit reported that 45° to 52° F. was more satisfactory for storage of grapefruit than the lower temperatures. More storage pitting developed on grapefruit stored at 38° to 40° than at the higher temperatures.

Florida grapefruit is exported in both refrigerated and ventilated holds of ships. Temperatures of the ventilated holds range from 35° to 95° F. (*3, 16, 17, 41*). Winston and Cubbedge (*41*) recommended a 50° temperature in refrigerated holds for exporting Florida grapefruit to reduce decay and pitting at destination. They also noted that more rind breakdown developed in grapefruit shipped in the refrigerated holds than in the ventilated holds. They recommend that fruit for export be treated with sodium orthophenylphenate plus hexamine solution and packed with biphenyl-treated packing materials to reduce decay.

As the result of a series of oversea tests with spring-harvested fruit in ventilated holds, Hatton and Winston (*17*) emphasized the requirement for cool ambient temperatures in transit. Fair success was obtained with grapefruit exported in mid-March, but results in April and May were not good.

Experimental export shipments of grapefruit by Oberbacher (*28*) and Oberbacher, Husmann, and Grierson (*29*) revealed that early-harvest, nonethylened, unwaxed grapefruit shipped in ventilated holds would successfully degreen en route, and with less pitting and decay than ethylene-treated fruit.

The most promising facility for maintaining grapefruit quality during export shipment is the refrigerated highway-type trailer van (*3*). Although the initial test was experimental, the method insures a minimum number of handlings and good temperature and humidity control.

MATERIALS AND METHODS

Simulated Export and Market-Storage Tests

1961–62

Marsh Seedless and Ruby Red grapefruit were harvested in October and December 1961 and March and May 1962 from commercial groves in Indian River and Lake Counties, Fla. Fruit from each harvest was divided into two randomized samples, one of which was placed in a degreening room and subjected to ethylene gas for 36 to 38 hours. Commercially, grapefruit are usually not degreened after January; however, in this study one lot was degreened in each test period.

Test fruit was treated as follows: Not washed, washed only, or washed and waxed with water-emulsion wax containing 10 percent solids. All fruit was packed in 4/5-bushel wirebound crates with two 11- by 17-inch biphenyl-impregnated pads. Each storage lot was composed of 4 to 6 crates, averaging 48 fruit each, from each harvest, treatment, and variety and for each storage temperature. The fruit was stored for 3 weeks at 32°, 40°, 50°, and 60° F. to simulate the export transit period. Each storage test was followed by a simulated marketing period of 2 weeks at 70°.

All test fruit was inspected for rind breakdown, decay, and other defects at the end of the 3-week storage or simulated transit period and again after the first and second week at 70° F. The biphenyl pads were discarded after the 3-week simulated transit period. Such physiological disorders as pitting and aging were classed as rind breakdown.

Decayed fruits were discarded at each inspection, whereas those showing rind breakdown were held with the sound fruit.

The color of grapefruit was determined by matching with one of the standard colors in plate 4 presented by Harding and Fisher (*11*).

1962–63

Marsh Seedless and Ruby Red grapefruit were harvested in October 1962 and February and April 1963 from the same commercial grove in Indian River County as in 1961–62. The test fruit was handled and prepared in a similar manner except that only the October fruit received the ethylene treatment. Each storage lot consisted of four to six wirebound crates from each harvest, treatment, variety and storage temperature. The fruit was stored for 3 weeks at 50° and 60° F., followed by 2 additional weeks at 70°.

In addition, in the February and April tests, grapefruit were stored for 3 weeks at 50° F., simulating an export period, followed by a simulated posttransit storage period of 6 weeks at 40°, 50°, and 60°. Also included in the February and April tests were pretransit holding tests of 5 and 10 days at 40° and 50°, followed by a 3-week simulated transit period at 50° and a 2-week, 70° holding period. Each pretransit and posttransit treatment was composed of two to four test crates.

All test fruit was inspected for rind breakdown, decay, and other defects at the end of the 3-week storage or simulated transit period and again after the first and second week at 70° F. Fruit was inspected weekly during the 6-week posttransit storage period.

1963–64

Marsh Seedless and Ruby Red grapefruit were harvested in October 1963 and February and April 1964 from the same grove as the fruit in the 1962–63 tests. The test fruit was handled and prepared in a manner similar to that in the 1962–63 season. Only the October test fruit received the ethylene treatment. The temperatures of the simulated export tests were 40°, 50°, and 60° F. Each storage lot was comprised of four to six wirebound crates from each harvest, treatment, variety, and storage temperature. Additional simulated export tests included pretransit treatment in which fruit waxed with a solvent wax, or immersed for 5 minutes in hot water (128°) and waxed with a solvent wax, were packed with biphenyl pads before storage at 40°, 50°, or 60°; similar treatments were made without biphenyl pads before storage at 60° only. Pretransit and posttransit storage tests at 40°, 50°, and 60° were also included. Inspection of the test fruit was made in a manner similar to the fruit in the 1961–62 and 1962–63 simulated export and market-storage tests.

Accompanied Export Tests

An observer accompanied export shipments of Marsh Seedless and Ruby Red grapefruit from Tampa, Fla., to Hamburg, West Germany, in April 1962, October 1962, and February 1964. Test fruit for all shipments was obtained from the Indian River source and treated by one of the following methods: Washed only; washed and water waxed; washed and waxed with a solvent wax containing orthophenylphenol and biphenyl; or washed, immersed in hot water at 128° F., for 5 minutes, and waxed with solvent wax. Two biphenyl pads were enclosed in all cartons except those containing fruit that had been treated with the fungicidal wax. In the October test, half of the fruit in each of these treatments was degreened by ethylene 36 to 43 hours. The others were not degreened. Each test lot consisted of 6 to 10 cartons from each variety, treatment, and transit temperature.

Test cartons of fruit were placed in the center of the refrigerated holds of the ships; the thermostats were set at 60° F. in the October test, and at both 50° and 60° in the February and April tests; test cartons were placed in a ventilated hold also for all three tests. Air and fruit temperatures were taken throughout the trip by thermistors and small thermographs. Carbon dioxide-oxygen content and relative humidity of the hold atmospheres also were measured. The fruit was inspected for decay and rind breakdown upon arrival at Hamburg and after 1- and 2-week holding periods at 60°.

RESULTS AND DISCUSSION

Simulated Export Tests

The harvest season for Florida grapefruit was divided into three periods: Early-harvest fruit was picked with minimum maturity standards, usually in October; midseason-harvest fruit was picked about mid-February or early March; and late-season harvest fruit was usually picked in April or May, when it is considered very ripe. These periods more or less conformed with the three distinct periods of maturity and ripening as described by Harding and Fisher (*11*).

Degreening of Early-Season Grapefruit

The effects of pretransit treatment and the export transit temperatures on degreening of early-harvest Marsh grapefruit are shown in figure 1. Fruit changed from dark green to a light green rind color during the 36- to 38-hour degreening treatment. Thereafter the rind color of both the washed-only and washed-and-waxed fruit changed to light yellow to yellow during the transit and holding periods. Washed fruit that received no degreening and no waxing degreened naturally to a yellow rind color during the 3-week 50° and 60° F. transit and the 2-week 70° holding periods.

Nonethylened, waxed grapefruit did not degreen sufficiently during the 3-week transit period at 32°, 50°, or 60° F. nor the 2-week holding period at 70° to attain an acceptable yellow color.

Although December-harvested fruit had degreened naturally on the tree from a dark green to a light green, 36 to 38 hours of degreening with ethylene were required to attain a light yellow rind color. Fruit receiving the degreening treatment were light yellow before transit and yellow to yellow-orange after the transit and holding periods. Nondegreened but waxed fruit attained a light yellow-green rind color during the simulated transit and holding periods. Washed-only fruit also attained a yellow to a yellow-orange rind color during the 3-week export transit period at 50° and 60° F.

Degreening after harvest, whether with or without ethylene treatment, is necessary from September to about January for consumer acceptance of grapefruit. Waxing retards degreening at all temperatures. However, washed-only fruit will degreen naturally during a 3-week export transit period at 50° or 60° F.

The Effects of Waxing

In certain European countries, there are objections to chemicals, waxes, and fungicides on fruit. This raises the question of the effect of merely washing fruit compared to the effect of various additives that are used commercially. The previous discussion shows that early-season unwaxed but washed grapefruit naturally degreens during the 3-week export transit period at 50° or 60° F.

The effects of washing, waxing, and three temperatures on the development of rind breakdown and decay of grapefruit during simulated export and holding periods are shown in figure 2. Grapefruit would not be shipped commercially either unwashed or at 40° F., but both temperature and waxing markedly affected the development of pitting. Pitting was not eliminated by waxing, but considerable reduction was attained. This is in agreement with the findings of Brooks and McColloch (*2*) and Davis and Smoot (*5*). At 50°, both waxed samples of fruit had less rind breakdown than the washed-only sample, but the unwashed fruit also developed only a small amount of rind breakdown. Little rind breakdown developed on any of the lots at 60°.

Waxing had less effect on decay development than on rind breakdown, but the trend was similar.

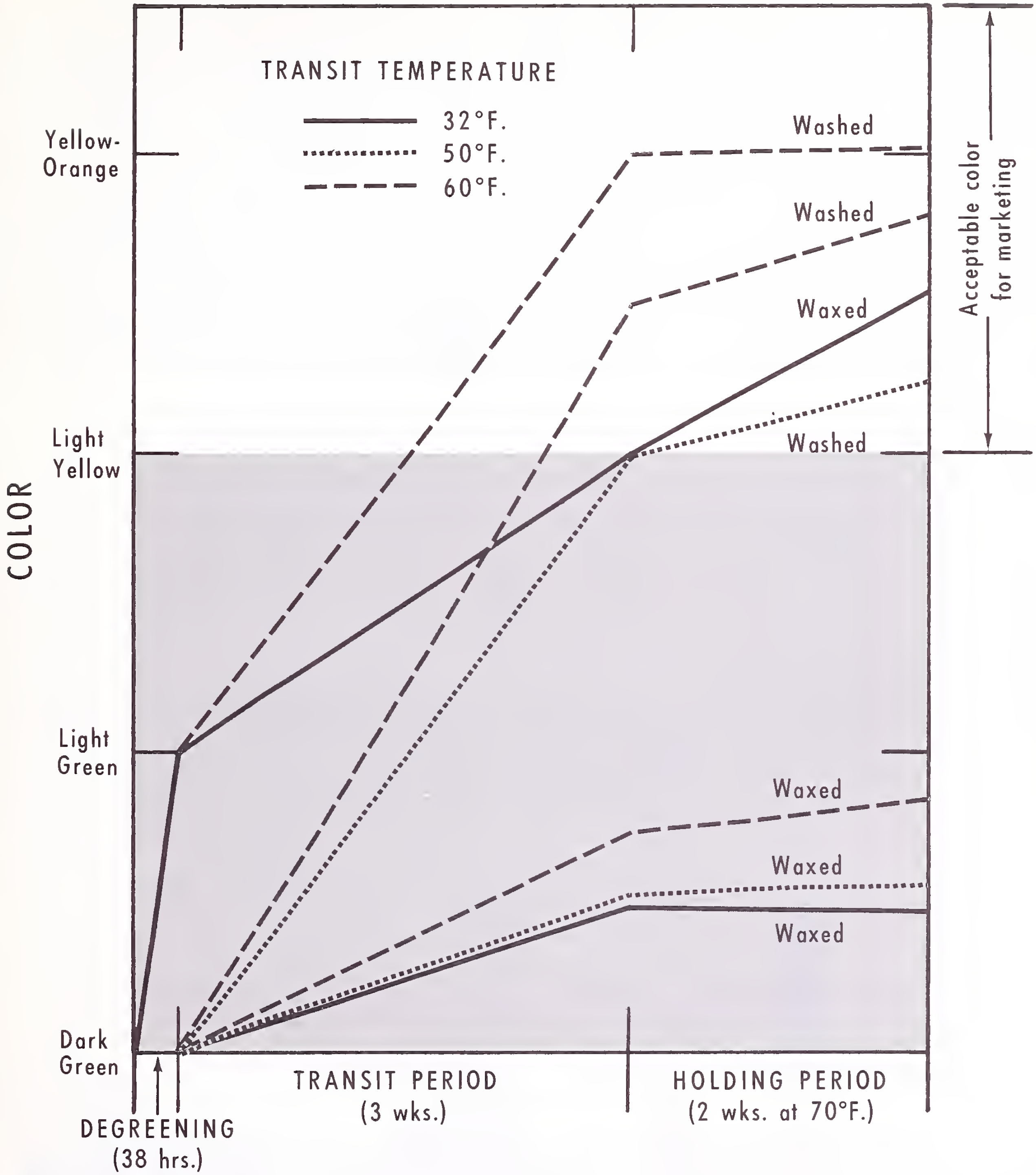

FIGURE 1.—Effects of pretransit treatment and export transit temperatures on degreening of Marsh grapefruit, October 1961.

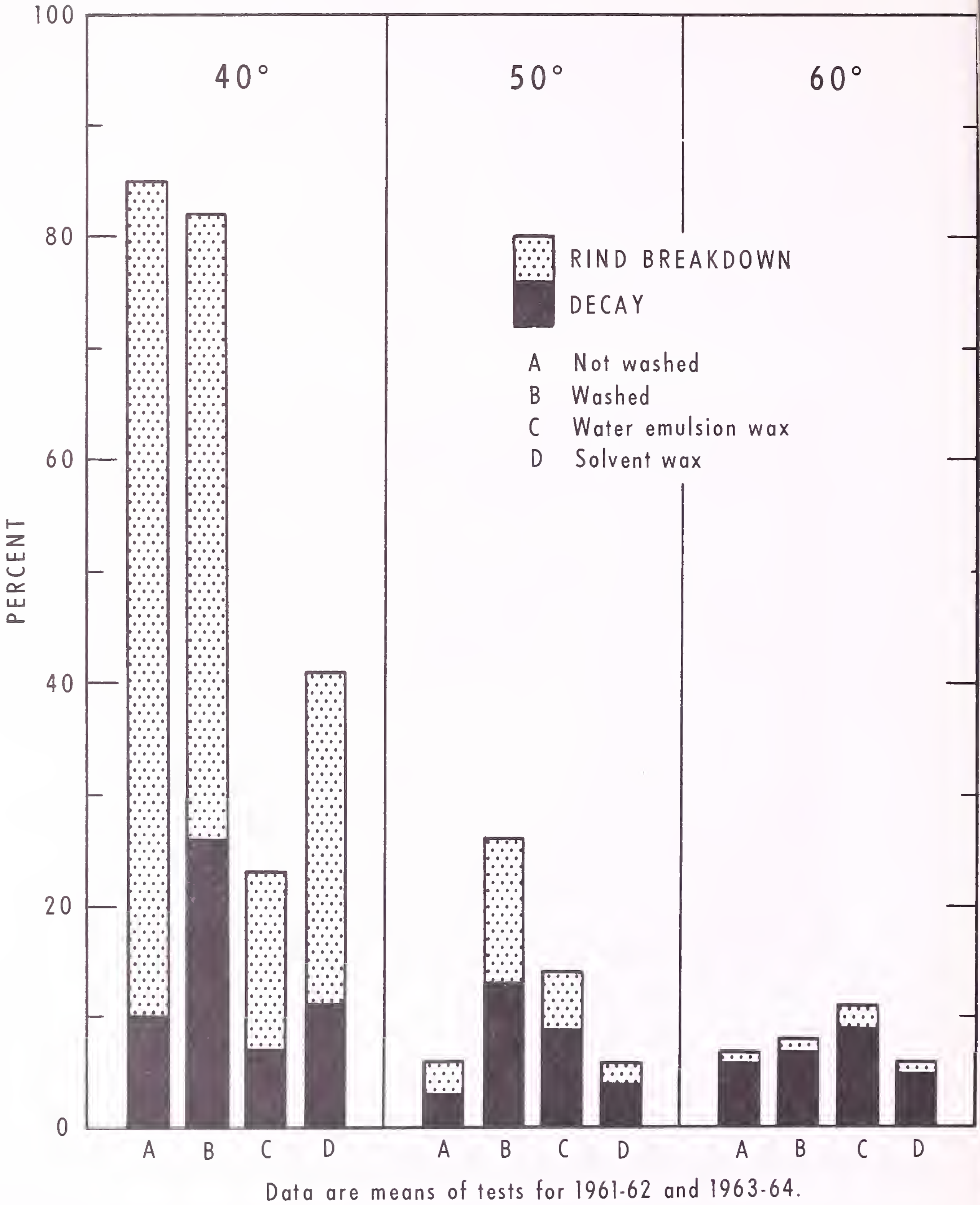

FIGURE 2.—Effects of washing, waxing, and three temperatures on the development of rind breakdown and decay of grapefruit after a 3-week simulated transit period and 2 weeks at 70° F. All crates contained two biphenyl pads.

At 40° and 50° F., waxed fruit generally developed less decay than fruit that had been washed-only, but more than unwashed fruit. There was little difference in the amount of decay in fruit given the various treatments and held at 60°.

The Effects of Decay Control Treatments

Reports of excessive decay in grapefruit exported to European markets have been received frequently. Grapefruit is considered less susceptible to decay than oranges, but a transit period of 3 days to the domestic market does not present the same problems as shipment to the European market some 2 to 3 weeks away.

Biphenyl pads were beneficial in reducing decay in the 3-week simulated export period at 50° and 60° F. and the 2-week holding period at 70° (table 1). A 5-minute 128° hot-water treatment plus a solvent wax also reduced decay. These results are shown in table 1. Further studies are necessary to determine conclusively whether a hot-water treatment would be of benefit in the export shipment of grapefruit.

TABLE 1.—*Percentage of Florida grapefruit with decay after a 3-week simulated transit period plus 2 weeks at 70° F., by type of pretransit treatment and transit temperature, 1963–64*

Pretransit treatment	Average number of fruit per storage temperature	Decay: With biphenyl pads, 40° F.	Decay: With biphenyl pads, 50° F.	Decay: With biphenyl pads, 60° F.	Decay: Without biphenyl pads — 60° F.
		Percent	*Percent*	*Percent*	*Percent*
Washed	992	26	5	6	11
Water wax	622	11	8	6	14
Solvent wax	592	14	5	4	23
Hot water plus solvent wax	920	7	3	3	12

Refrigeration is also a method of decay control. Less decay will develop at 50° F. than at higher temperatures. Fifty degrees should be used when decay is the only consideration; however, a slight increase in rind breakdown may occur at this temperature particularly with early-harvest fruit. The effect of temperature on green-mold decay following artificial inoculation is shown in table 2. The incidence of decay and rate of development increased rapidly as the temperature increased from 50° to 70° with both Ruby Red and Marsh Seedless varieties throughout the harvest season. The results of the test using fruit artificially inoculated could be compared with fruit mechanically injured during loading and without chemical treatment for decay reduction.

TABLE 2.—*Percentage of Florida grapefruit infected by green mold and size of infection 4 days after artificial inoculation, by variety, time of harvest, and storage temperature, 1962–63*

[Each figure based on 100 inoculations]

Variety and time of harvest	Fruit infected 50° F.	Fruit infected 60° F.	Fruit infected 70° F.	Diameter of decay 50° F.	Diameter of decay 60° F.	Diameter of decay 70° F.
	Percent	*Percent*	*Percent*	*Millimeters*	*Millimeters*	*Millimeters*
Marsh Seedless:						
October	0	57	68	0	11	37
February	21	48	65	8	26	69
June	0	53	92	0	11	62
Ruby Red:						
October	0	52	76	0	12	46
June	3	92	93	5	13	73

Pretransit Holding Tests

In accumulating large lots of grapefruit for export, some fruit may be held as long as 10 days before shipment. If an extended holding period is required before shipment, proper storage conditions are necessary to reduce spoilage. Table 3 shows the results of holding grapefruit for 5 and 10 days at 40°, 50°, and 60° F. before a 3-week simulated transit period at 50° or 60° and a 2-week marketing period at 70°.

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TABLE 3.—*Percentage of Florida grapefruit with rind breakdown and decay in simulated transit tests after specified periods, by variety, time of harvest, and pretransit and transit temperatures, 1963–64*

Variety and time of harvest	Average number of fruit per treat-ment	Transit temper-ature	3-week transit plus 2-week, 70° F. holding period		5-day pretransit plus 3-week transit plus 2-week, 70° F. holding period						10-day pretransit plus 3-week transit plus 2-week, 70° F. holding period					
					40° F.[1]		50° F.[1]		60° F.[1]		40° F.[1]		50° F.[1]		60° F.[1]	
			Rind break-down	Decay	Rind break-down	Decay	Rind break-down	Decay	Rind break-down	Decay	Rind break-down	Decay	Rind break-down	Decay	Rind break-down	Decay
Marsh Seedless:		° F.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Early season[2]	145	60	0	4	0	2	0	6	0	8	8	9	6	8	0	9
Midseason	148	50	0	8	4	8	0	8	2	9	12	20	1	4	0	13
Late season	146	50	4	11	5	13	4	18	18	13	10	12	10	14	5	17
Ruby Red:																
Early season[2]	145	60	0	1	0	11	1	10	1	8	0	2	2	3	0	7
Midseason	148	50	0	7	1	9	1	4	0	7	4	9	1	7	0	14
Late season	146	50	0	6	2	13	4	10	4	11	2	17	3	9	1	8

[1] Pretransit temperature.
[2] Fruit degreened with ethylene for 46 hours prior to storage.

Inspection of the fruit after the 5- or 10-day holding period at all temperatures revealed no rind breakdown nor decay. After the 3-week storage and 2-week holding periods, little or no rind breakdown was noted in the fruit held for 5 days with the exception of the late-season fruit held at 60° F. However, as the pretransit holding period was increased to 10 days, substantial amounts of rind breakdown occurred following the 40° holding plus 3-week storage and 2-week holding periods.

By increasing the pretransit holding period, generally an increase in decay can be expected, although the effect of the pretransit holding period was not as obvious for decay as it was for rind breakdown.

Fruit should be held for as short a period as possible before transit and at the designated export transit temperature to minimize rind breakdown and decay.

Simulated Export Transit Tests

The summary of results for the 3 years presented in figures 3, 4, and 5 shows the effect of transit temperatures and maturity of Marsh Seedless and Ruby Red grapefruit on rind breakdown and decay.

Early-Harvest Fruit.—The early-harvest test fruit had a minimum solids-to-acid ratio of 7 to 1, as required by the Florida citrus maturity laws (*6*).

A 60° F. temperature was best for degreened early-harvest fruit, as indicated by the absence of rind breakdown at removal from storage and after a 2-week 70° holding period (fig. 3). In comparison, rind breakdown in the test fruit from 50° storage ranged from 2 to 5 percent upon removal from storage and from 5 to 7 percent after a 2-week holding period, with little difference between Marsh Seedless and Ruby Red grapefruit. After storage at a simulated transit temperature of 40°,

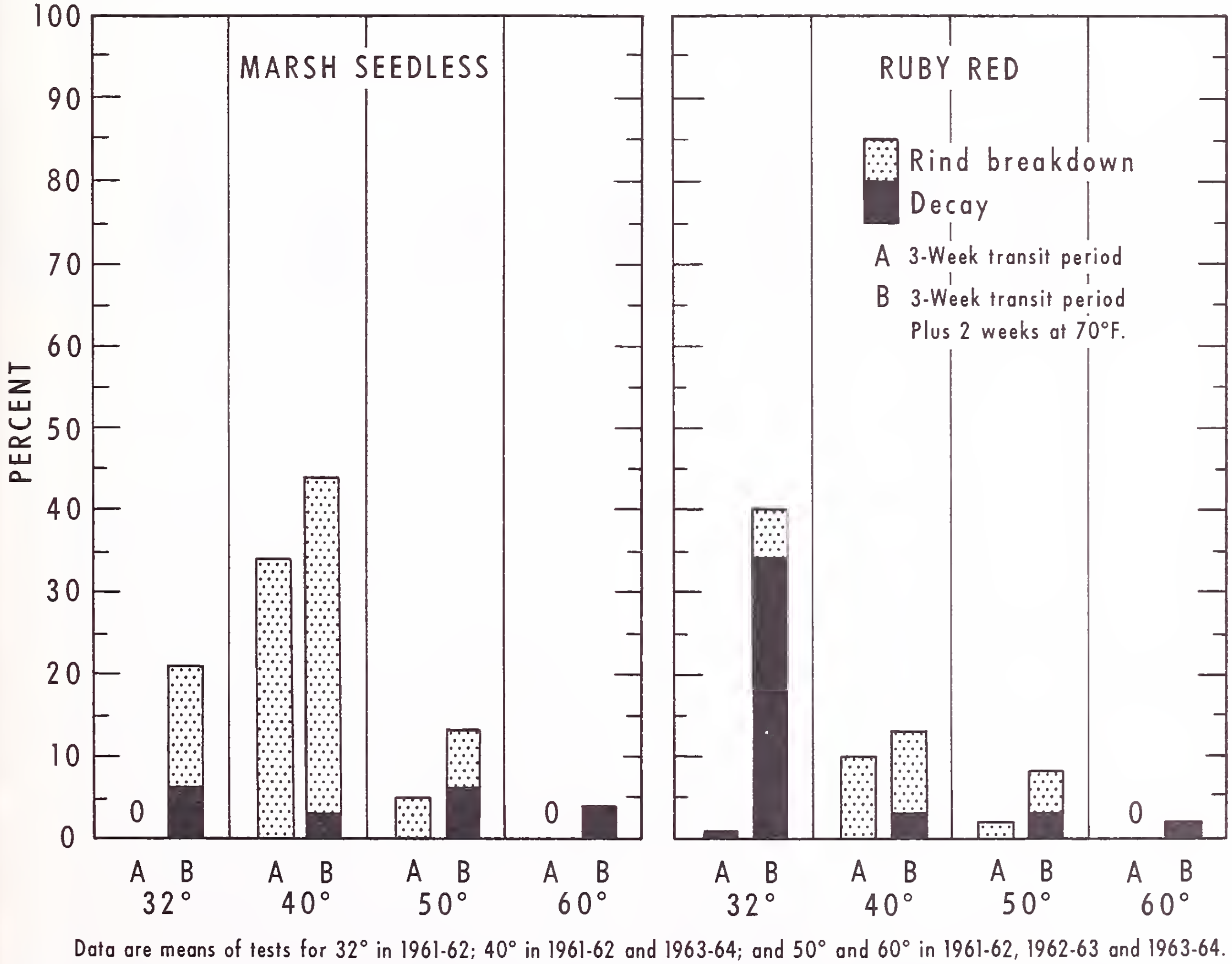
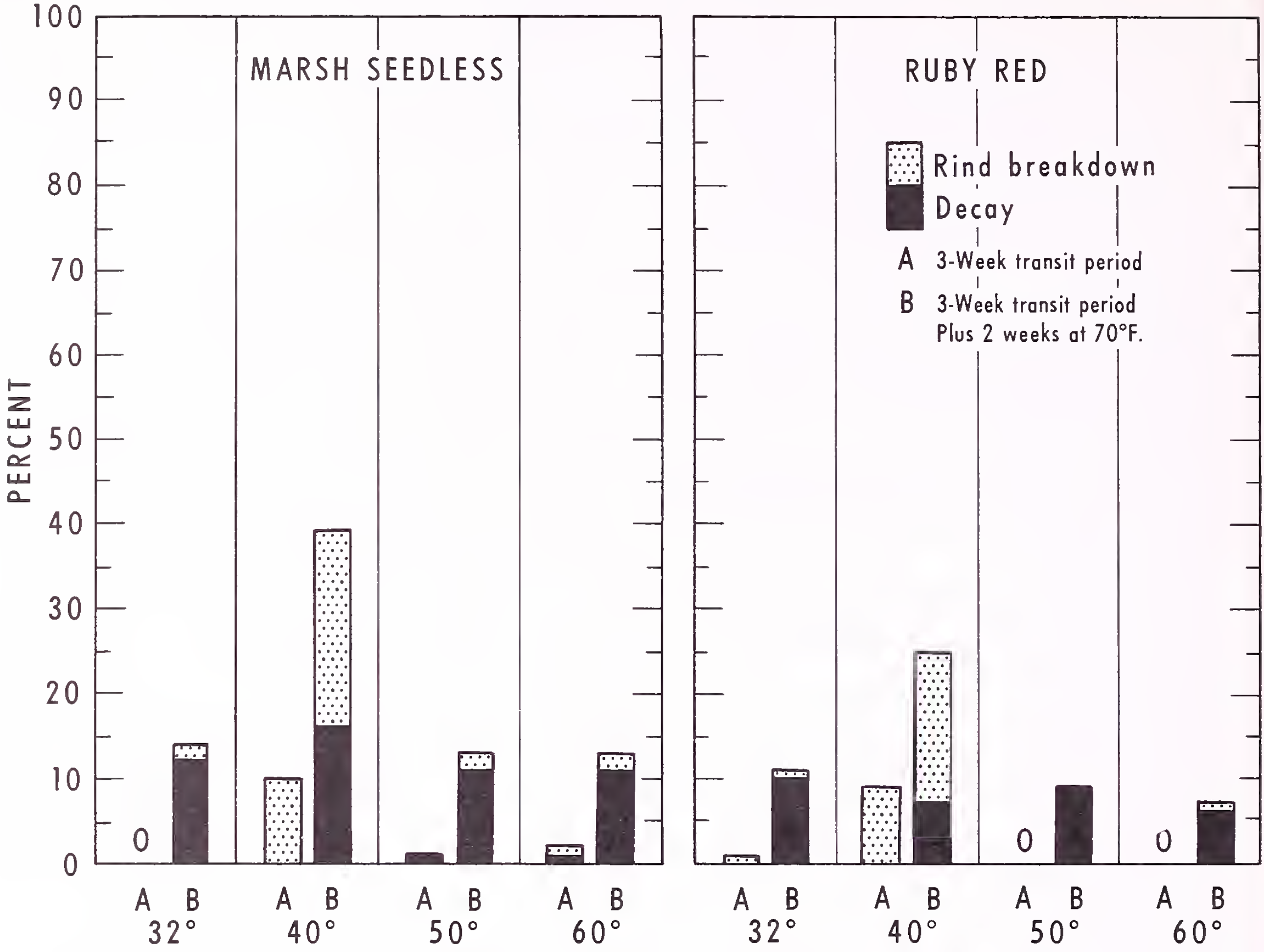


Figure 3.—Rind breakdown and decay of degreened early-harvest grapefruit during simulated export tests. Fruit was degreened with ethylene for 36 to 46 hours.



Data are means of tests for 32° in 1961-62; 40° in 1961-62 and 1963-64; and 50° and 60° in 1961-62, 1962-63 and 1963-64.

FIGURE 4.—Rind breakdown and decay of midseason grapefruit during simulated export tests.

34 percent rind breakdown developed in the Marsh Seedless and 10 percent in the Ruby Red grapefruit. The lots stored at 32° developed no rind breakdown during the 3-week storage period. However, after 2 additional weeks at 70°, Marsh Seedless grapefruit developed 15 percent rind breakdown, and Ruby Red grapefruit developed 6 percent. Severe symptoms of brown staining developed on 10 to 53 percent of the fruit stored at 32°. After 3 weeks at 32°, brown staining appeared as a barely discernible light brown discoloration; but after the fruit was held for 2 weeks at 70°, the brown-staining area intensified from light to dark brown and increased in the area affected.

Fruit was harvested in December 1961–62 also, but results of that study are not included in data in figure 3. As in the early-harvest (October) fruit, less breakdown developed following a simulated transit period at 60° F. than at lower temperatures for both varieties of grapefruit.

Less than 2 percent decay occurred in all test lots of fruit during the 3-week simulated transit period. Most of the decay developed during the 2-week 70° F. holding period. Least decay developed in the grapefruit stored at 60°, with only slightly more decay developing in the fruit stored at 40° or 50°. The greatest amount of decay developed in grapefruit stored at 32°.

MIDSEASON-HARVEST FRUIT.—The solids-to-acid ratio of fruit picked in midseason averaged 9.5 to 1. Commercial grapefruit do not normally require degreening treatment at this time.

Little difference was noted in the amount of rind breakdown that developed in grapefruit held at 32°, 50°, or 60° F. (fig. 4). In the early fruit, most of the rind breakdown was classed as pitting (fig. 3). However, rind breakdown in midseason test fruit consisted of both pitting and aging (fig. 6). Grapefruit held at 40° developed commercially significant amounts of rind breakdown,

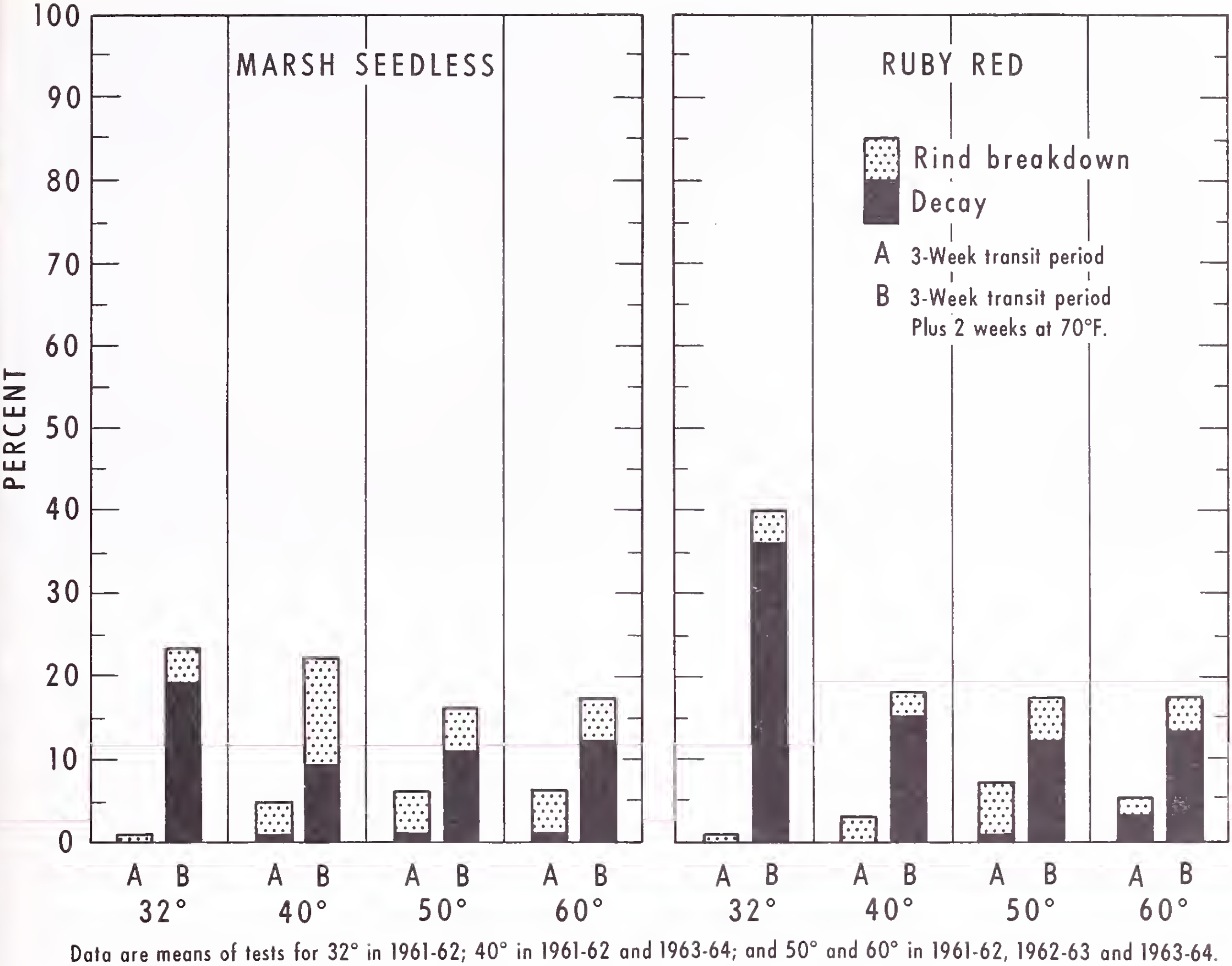


FIGURE 5.—Rind breakdown and decay of late-harvest grapefruit during simulated export tests.

which increased considerably during the 2-week 70° holding period.

Midseason-harvest fruit developed more decay at most temperatures than early-harvest fruit. Very little of this decay developed during the 3-week simulated transit period. During the 2-week 70° F. holding period, fruit previously held at 50° and 60° developed 6 to 11 percent decay, with little difference between these temperatures or between varieties. The development of decay in fruit previously held at 32° and 40° varied from 7 to 16 percent; Marsh Seedless grapefruit had the most decay.

LATE-HARVEST FRUIT.—The solids-to-acid ratio of Marsh Seedless and Ruby Red grapefruit picked for the late tests averaged 12 to 1.

Most of the rind breakdown that developed on the late-harvest fruit was classed as aging. The storage or export transit temperatures had little effect on controlling its development. Late-harvest grapefruit that developed aging during the export transit period had a tendency to develop greater amounts of decay during the 70° F. holding period (fig. 5).

Because of excessive decay development, no simulated transit temperature was satisfactory for late-harvest fruit. Little decay developed during the 3-week storage period, but during the 2 weeks at 70° F. much decay occurred. Fruit held at 32° developed 19 to 34 percent decay, considerably more than at the other storage temperatures.

Relation of Pitting, Aging, and Decay to Maturity and Storage Temperature

It is apparent from the data presented in the previous sections that the response of grapefruit to maturity and export transit or storage temperatures shows a definite pattern. Figure 7 shows the effect of maturity for the 3 years of this study on the development of pitting, aging, and decay without regard to the transit or storage temperature. Early-harvest grapefruit are most susceptible to

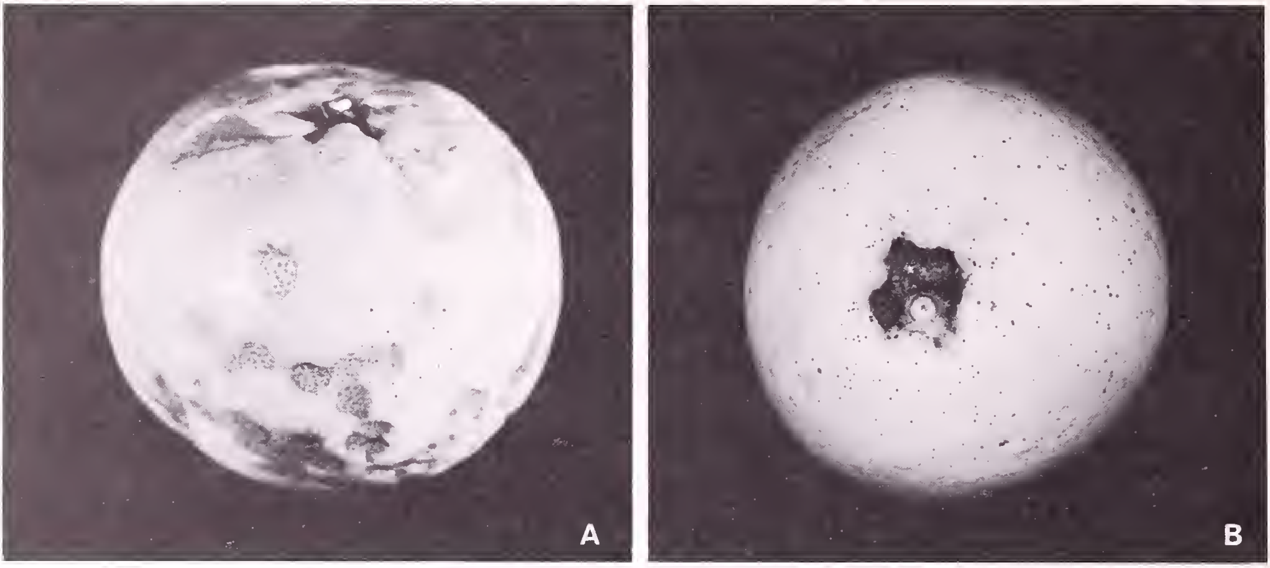


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FIGURE 6.—(A) Severe pitting symptoms on grapefruit held for 3 weeks at 40° F. (B) Aging on grapefruit stored for 3 weeks at 50° followed by 2 weeks at 70°.

pitting; susceptibility to pitting gradually decreases as the fruit becomes more mature. The susceptibility of grapefruit to aging and decay is in direct contrast to its susceptibility to pitting, in that aging and decay gradually increase with maturity.

A similar relationship can be shown for the response of grapefruit to transit or storage temperatures without regard to maturity. The effects of temperature on the development of pitting, aging, and decay of grapefruit stored for 3 weeks at 32°,

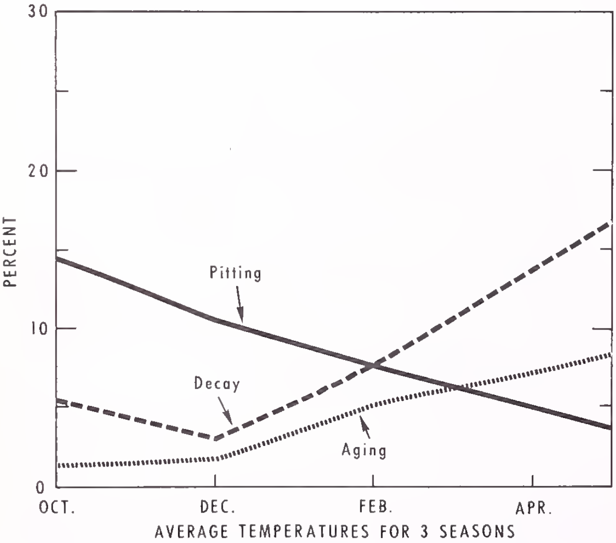

FIGURE 7.—Susceptibility of grapefruit, harvested at four maturities, to pitting, aging, and decay after a 3-week storage period and 2 weeks at 70° F.

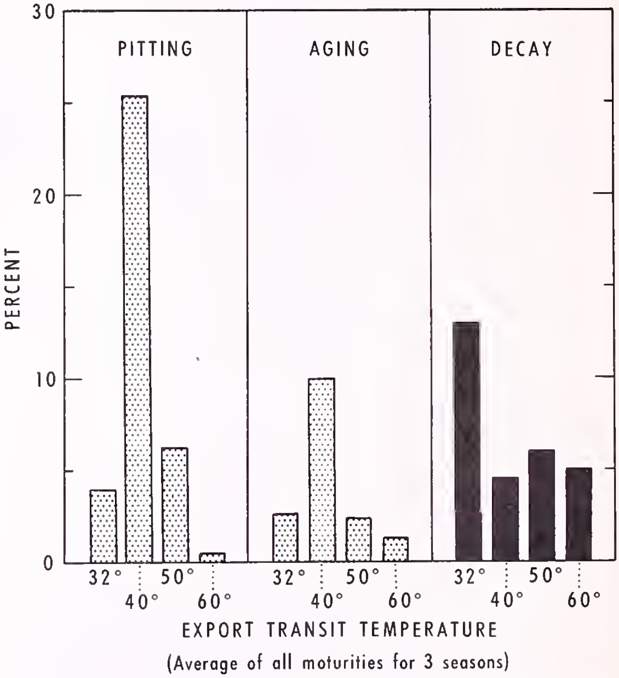

FIGURE 8.—Susceptibility of grapefruit to pitting, aging, and decay after a 3-week storage period at 32°, 40°, 50°, or 60° F. plus 2 weeks at 70°.

40°, 50°, or 60° F. plus 2 weeks at 70° are shown in figure 8. The development of pitting of grapefruit is directly related to the storage temperature. The least amount of pitting developed in the fruit held at 60°, and the greatest in the fruit held at 40°. Aging developed in a pattern similar to that of pitting, with the greatest susceptibility at 40°. However, temperatures of 32°, 50°, and 60° do not appear to affect the development of aging. The greatest amount of decay occurred in the fruit held at 32°; most of the decay developed during the 2-week holding period. Little difference was noted in the subsequent development of decay following storage at 40°, 50°, and 60°.

Long-Term Storage of Grapefruit After Simulated Oversea Transit

There are times when exported fruit is scheduled for storage at destination. To insure minimum spoilage and maximum storage life, optimal storage conditions must be provided.

The results of a 3-week simulated export transit period at 60° or 50° F. and a subsequent 6-week storage period of Marsh grapefruit are shown in table 4.

Although early-harvest fruit stored at 40° F. after 60° transit developed the least decay, development of extreme amounts of rind breakdown during the third week of storage would preclude the use of this temperature. A similar trend can be noted with rind breakdown after 50° storage. No rind breakdown developed when fruit was both shipped and stored at 60°. These data indicate that early-harvest fruit could be held at 60° for 4 weeks after transit at that temperature with development of little rind breakdown or decay.

The best transit and storage temperature for midseason shipments was 50° F. Fruit shipped at 50° but stored at 60° developed excessive amounts of decay after the third week of storage. Fruit shipped at 50° and held at 40° developed progressive amounts of rind breakdown (pitting and aging).

Shipment and storage of late-season fruit could be risky as late-season fruit is most susceptible to development of stem-end decay. Storage at 60° F. was not satisfactory for fruit that had been shipped at 50°; decay developed rapidly after the first week of storage. Shipping and storage at 50° resulted in only slight rind breakdown, but decay increased rapidly after the third week. Fruit shipped at 50° and stored at 40° had the least amount of decay, but rind breakdown was slightly more prevalent than at the higher storage temperatures.

The data for Ruby Red grapefruit are not shown in table 4, as little difference was noted in the condition of Marsh Seedless and Ruby Red grapefruit throughout these tests.

TABLE 4.—*Percentage of Marsh Seedless grapefruit with rind breakdown and decay after 3 weeks' transit and specified posttransit periods, by time of harvest and storage temperature, 1963–64*

Time of harvest	Average number of fruit per treatment	3-week transit temperature	Post-transit storage period	Storage temperature— 40° F. Rind breakdown	40° F. Decay	50° F. Rind breakdown	50° F. Decay	60° F. Rind breakdown	60° F. Decay
		° F.	*Weeks*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Early season [1]	274	60	0	0	1	0	0	0	1
			1	0	1	0	0	0	1
			2	1	1	0	1	0	1
			3	23	1	3	2	0	2
			4	51	1	3	3	0	5
			5	82	1	3	5	0	10
			6	82	1	14	9	0	12
Midseason	274	50	0	1	0	0	2	0	1
			1	2	0	0	2	0	1
			2	3	0	0	2	0	1
			3	4	0	0	2	0	3
			4	5	0	0	2	0	6
			5	7	0	0	4	0	17
			6	15	0	0	6	0	22
Late season	344	50	0	1	1	3	1	1	0
			1	2	1	4	1	4	1
			2	4	1	4	3	5	7
			3	4	1	4	4	4	17
			4	4	2	4	7	3	21
			5	5	2	4	10	3	31
			6	7	2	4	13	3	37

[1] Fruit degreened with ethylene for 46 hours before transit and storage

Early and midseason grapefruit destined for storage upon arrival should be held at the optimum export transit temperature for not longer than 4 weeks, or a total time of 8 weeks from harvest. Storage of late-season fruit is not recommended because of the decay potential. If decay is excessive during transit, the fruit should be marketed immediately after arrival.

Accompanied Export Test Shipments

An observer accompanied export shipments of Florida grapefruit in October, February, and April from Tampa, Fla., to Hamburg, West Germany.

Temperature

Temperatures of the test fruit shipped in refrigerated holds reached constant levels of 50° or 60° F. within 3 days after loading, with one exception: Fruit in the 50° hold of the February shipment took 10 days to attain the desired level. Temperatures at all positions were maintained within ±3° to the first European port (generally Le Havre). Opening of the hatches in the subsequent three or four ports, where temperatures were usually lower than temperatures specified for the hold, lowered fruit temperatures 3° to 5° below those desired.

Fruit temperatures in ventilated stowages closely paralleled that of outside air delivered to the holds by ventilation fans. Because of the daily fluctuations, fruit temperatures in the different positions in the ventilated holds varied as much as 6°. Temperatures of the fruit during transit varied with the time of season of the shipment; each trip had its distinctive temperature pattern (fig. 9).

Relative Humidity

The most difficult condition to maintain during transit was relative humidity. In the October and April tests, fruit was shipped in refrigerated holds designed for hauling nonfrozen but refrigerated commodities. The relative humidity in refrigerated holds had increased from 55 to 70 percent to 80 percent during the first 3 days of transit, and varied from 80 to 90 percent during the remainder of the transit period.

In the February test shipment, difficulties were encountered in establishing and maintaining temperature and relative humidity, as the refrigerated holds were designed basically for transporting frozen cargo. Large variable-speed circulating fans were used to introduce outside air to maintain the highest possible level of relative humidity.

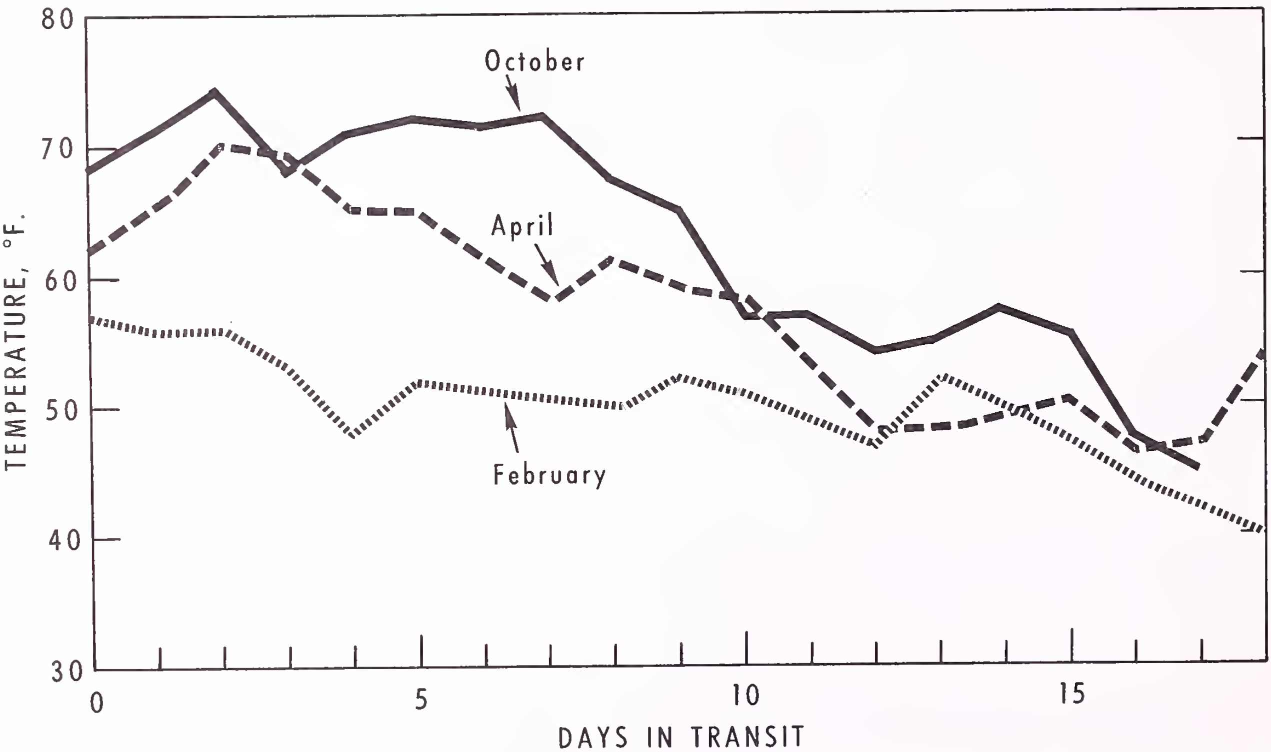

FIGURE 9.—Average temperatures of grapefruit at middle layer, centerline position in ventilated holds during shipments from Tampa, Fla., to Hamburg, West Germany.

The relative humidity in the 50° and 60° F. refrigerated holds varied from 54 to 82 percent.

Relative humidity in the ventilated holds varied considerably, ranging from 54 to 95 percent; it was affected by the presence of other types of cargo stowed in the hold.

Carbon Dioxide

The carbon dioxide content of the atmospheres in the refrigerated holds was measured at intervals throughout transit. During the second day of the October trip, carbon dioxide increased from 0.2 to 1.3 percent in 4 hours, at which time the hold was aerated. Standard procedure was to aerate the holds daily to prevent any major buildup of carbon dioxide. Large lots of fruit in a fairly tight refrigerated hold may produce substantial carbon dioxide.

October 1962 Test

No rind breakdown developed in any of the test fruit during the 3-week transit period or during the 2 weeks at 60° F. in the October 1962 test. Decay upon arrival at Hamburg was 2 percent or less, and after the 2-week holding period it was 6 percent or less (table 5).

The test fruit that was washed but not waxed changed from green to an acceptable yellow rind color during transit. However, washed-only fruit shipped in ventilated stowage was considered unmarketable after the 2-week holding period because of excessive shriveling. The waxed fruit shipped under refrigeration or ventilation remained in a marketable condition even after a 2-week holding period.

No effect on the development of rind breakdown or decay could be attributed to treatment or variety, as little rind breakdown or decay developed during this test.

February 1964 Test

Fruit in the February 1964 test was severely bruised during the rough voyage to Europe. The severity of the bruising varied from lot to lot, as evidenced by the variation in the development of decay during the 2-week holding period (table 6). Decay upon arrival was generally less than 5 percent and increased rapidly to 6 to 37 percent during the 2 weeks at 60° F. The fruit that was only washed usually developed less decay than the other lots. However, these fruits were considered unmarketable after the 2-week holding period because of excessive shriveling. No differences between the other treatments could be isolated because of the large amount of decay. If rough weather is encountered during transit, it would be to the importer's advantage to market the fruit immediately.

For comparison, a simulated test was conducted at the same time as the accompanied export test. The development of decay during the 3-week simulated transit period and the 2 weeks at 70° F.

TABLE 5.—*Percentage of Florida grapefruit with decay after shipment in cartons [1] to Hamburg, West Germany, and after 1 or 2 additional weeks at 60° F., by variety, pretransit treatment, and type of stowage, October–November 1962*

Variety and pretransit treatment [2]	Degreened with ethylene	60° F. refrigerated stowage			Ventilated stowage		
		Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.	Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.
Marsh Seedless:	*Hours*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Washed	0	0	1	2	0	0	2
Washed and waxed	0	0	1	2	0	2	4
Commercial [3]	0	2	2	5	1	3	5
Washed	36	0	1	2	0	3	5
Washed and waxed	36	1	4	5	1	3	6
Commercial [3]	43	1	2	5	0	2	4
Ruby Red:							
Washed	0	0	1	2	0	0	2
Washed and waxed	0	1	2	3	0	1	2
Commercial [3]	0	2	2	3	1	2	4
Washed	36	0	2	3	2	2	4
Washed and waxed	36	2	2	4	1	2	4
Commercial [3]	43	0	1	2	1	1	3

[1] 8 ⅘-bushel cartons per treatment, with 36 to 56 fruit per carton.

[2] With the exception of commercially waxed lots, 2 biphenyl pads were placed in each carton; they were removed after the first inspection.

[3] Commercial application of solvent wax containing orthophenylphenol and biphenyl.

TABLE 6.—*Percentage of Florida grapefruit with decay after shipment in crates* [1] *to Hamburg, West Germany, and after 1 or 2 additional weeks at 60° F., by variety, pretransit treatment, and type of stowage, February–March 1964*

Variety and pretransit treatment [2]	50° F. refrigerated stowage			60° F. refrigerated stowage			Ventilated stowage		
	Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.	Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.	Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Marsh Seedless:									
Washed	2	6	23	1	6	17	2	4	18
Water emulsion wax	4	11	32	4	8	26	3	13	37
Solvent wax [3]	1	3	15	5	16	32	0	3	18
Hot water for 5 minutes at 128° F. + solvent wax	1	2	19	1	3	15	1	3	25
Ruby Red:									
Washed	0	2	6	2	6	15	0	1	12
Water emulsion wax	1	4	17	2	9	19	1	6	23
Solvent wax [3]	2	8	19	7	13	25	0	6	22
Hot water for 5 minutes at 128° F. + solvent wax	1	5	22	0	5	20	0	6	22

[1] 6 4/5-bushel wirebound crates per treatment with 27 to 48 fruit per crate.

[2] With the exception of fruit receiving wax containing fungicides, 2 biphenyl pads were placed in each crate; they were removed after the first inspection.

[3] Solvent wax containing orthophenylphenol and biphenyl.

is shown in table 7. Although no differences due to temperature or treatment were obvious in the export test, the results of the simulated test favored a 50° transit temperature. Lots waxed with solvent wax and those treated with hot water for 5 minutes and waxed with solvent wax developed the least amount of decay during the export transit period and 2-week, 70° holding period. Extra handling and the rough voyage during the accompanied test caused much more decay to develop in the accompanied test than in the simulated test.

In both the accompanied and the simulated export test, washed-only fruit showed shriveling during the holding period. The washed-only fruit in the accompanied shipment were unmarketable because of excessive shrivel at the end of the holding period.

April 1962 Test

No commercially significant rind breakdown developed during the voyage or the 2-week holding period in the April 1962 test. Less than 5 percent decay was noted in all test fruit on arrival in Hamburg. During the subsequent 2-week holding period at 60° F., the grapefruit exported at 50° developed less decay than fruit exported at 60° or under ventilation (table 8).

In this test, the Ruby Red grapefruit generally developed less decay than the Marsh Seedless. No important differences in condition were noted between the fruit that received various pretransit treatments.

Observations on Handling During Export

Although this research program was not designed specifically to study fruit handling during export, the need for improvement was obvious. The combination of indifferent shipping quality, rough handling, and improper stowage increased losses from spoilage and reduced market quality.

The procedure in harvesting and packing of fruit, although varying from packinghouse to packinghouse, is fairly standard. However, recent developments in the design of handling and packinghouse equipment and improved transportation vehicles have reduced fruit damage during this process.

Some fruit for export is transported from the packinghouse to a Florida port in an open or unrefrigerated trailer. Warming of the fruit during this transit period hastens its eventual deterioration. The fruit is sometimes held in unrefrigerated dockside warehouses for 2 to 7 days, which further shortens its market life.

Container

The ⅘-bushel corrugated container and ⅘-bushel wirebound crate are the two containers used for export of grapefruit. Neither container adequately protects the fruit from mechanical injury during export. The carton is weakened by the absorption of moisture from the fruit and the high humidity of the refrigerated hold. When cartons are stacked 10 to 12 high, the bottom cartons and the fruit in them are often damaged from the overhead weight. Overfilling of either

TABLE 7.—*Percentage of Florida grapefruit with decay after a 3-week simulated export test in wirebound crates*[1] *and after 1 and 2 additional weeks at 70° F., by variety, pretransit treatment, and storage temperature, February–March 1964*

Variety and pretransit treatment [2]	50° F. refrigerated storage			60° F. refrigerated storage		
	Arrival inspection	2d inspection, after 1 week at 70° F.	3d inspection, after 2 weeks at 70° F.	Arrival inspection	2d inspection, after 1 week at 70° F.	3d inspection, after 2 weeks at 70° F.
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Marsh Seedless:						
Washed	0	1	4	1	1	11
Water emulsion wax	1	2	8	1	5	9
Solvent wax	2	2	2	0	1	5
Hot water for 5 minutes at 128° F. plus solvent wax	1	1	2	0	0	3
Ruby Red:						
Washed	1	1	3	1	3	9
Water emulsion wax	0	2	8	0	1	10
Solvent wax	0	2	2	0	0	2
Hot water for 5 minutes at 128° F. plus solvent wax	0	0	3	1	1	7

[1] 4 ⅘-bushel wirebound crates per treatment, with 27 to 48 fruit per crate.

[2] 2 biphenyl pads were placed in each crate; they were removed after the first inspection.

TABLE 8.—*Percentage of Florida grapefruit with decay after shipment in cartons*[1] *to Hamburg, West Germany, and after 1 and 2 additional weeks at 60° F., by variety, pretransit treatment, and type of stowage, April 1962*

Variety and pretransit treatment[2]	50° F. refrigerated stowage			60° F. refrigerated stowage			Ventilated stowage		
	Arrival inspection	2d inspection after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.	Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.	Arrival inspection	2d inspection, after 1 week at 60° F.	3d inspection, after 2 weeks at 60° F.
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Marsh Seedless:									
Washed	2	2	6	2	7	11	2	5	9
Washed and waxed	1	4	6	4	9	14	4	7	13
Commercial[3]	1	2	4	4	6	13	4	5	11
Ruby Red:									
Washed	1	2	2	1	2	4	1	2	3
Washed and waxed	1	1	3	2	6	8	0	2	4
Commercial[3]	1	1	2	1	1	5	2	3	4

[1] 10 4/5-bushel cartons per treatment, with 40 to 56 fruit per carton.
[2] With the exception of commercially waxed lots, 2 biphenyl pads were placed in each carton; they were removed after the first inspection.
[3] Solvent wax containing orthophenylphenol and biphenyl.

container to produce a bulge may result in damage to all fruit in the container during loading and stacking.

Handling

The number of times a container is handled, as well as the manner in which it is handled, is an important factor in the condition of the fruit on arrival. Each container-equivalent of fruit is handled from 15 to 25 times in moving the fruit from the tree to the foreign consumer. Loading and unloading of the ships' holds are the roughest operations. The containers of fruit are thrown, walked on, and used for support of conveyors. The fruit injured by this rough treatment is susceptible to green mold development (fig. 10). Some attempts have been made to avoid walking on containers as shown in figure 11.

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FIGURE 10.—The roughest handling practices occur during loading and unloading. Containers are thrown, walked on, and used as support for conveyors.

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FIGURE 11.—Large plywood boards have been used successfully as walks to reduce damage to container and fruit during loading.

Stacking

Proper stacking and use of dunnage or stripping is the key to good circulation of air, uniform temperatures of commodities, and reduction of damage to products. As each ship presents a different stacking situation, detailed recommendations for proper stacking procedures are impractical.

The use of 1- by 1-inch dunnage with corrugated cartons often leads to damage to the carton and fruit. As the carton picks up moisture and weakens, it collapses around the dunnage and blocks the air circulation. Therefore, a wider dunnage, or no dunnage, is needed for exporting grapefruit in cartons. The narrow 1- by 1-inch dunnage can be used beneficially to augment air circulation around wirebound crates.

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The postharvest fungicides mentioned in this publication have been approved by the Food and Drug Administration *ONLY* if residues do not exceed the specified tolerances.

If postharvest fungicides are handled, applied, or disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use postharvest fungicides only when needed and handle them with care. Follow directions and heed all precautions on the container label.

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